NOT THE SEA AND NOT A LAKE: MEROMICTIC WATER BODIES SEPARATING FROM THE SEA

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Although our planet is called the Earth, most of its surface (71%) falls on the ocean. The boundary of the seas and land does not lie at the same place, but constantly moves, because the sea level can fall and rise as a result of tectonic movements. Relative rise in sea level when the sea moves toward higher ground, resulting in flooding, in geology is called a transgression. Opposite, if the sea level falls relative to the land and exposes former sea bottom, this is regression. By regression, part of the former marine area may be completely isolated. So the Aral and Caspian seas were formed, which once were an organic whole; the Black Sea was completely isolated from the ocean, and then again it merged with it. Large isolated sea areas usually stay the seas. But a small part of the sea area being isolated change a lot. The main role plays fresh water runoff, which strives to displace seawater. This, in particular, had occurred in the Black Sea, which in its intricate evolution passed through the stage of a fresh lake. On the sea coast there is always a confrontation between two forces - the sea and fresh water, and the result depends on which one will take over.

This can be observed in estuaries - areas of mixing of waters with different chemical composition. In the mixing zone of marine and fresh water, not only the dilution of sea water occurs, but many chemical and physical processes that can be observed. For example, upon contact of sulfates of sea water and calcium diluted in water of lowland rivers, poorly soluble gypsum is formed. It precipitates, and the salt composition of both marine and freshwater media changes radically. Complex transformations occur with dissolved organic substances and with a mineral suspension - they coagulate and precipitate. If the suspended matter prevail in the river waters, why they look muddy, then after mixing with salt water the dissolved forms predominate and the water is transparent. Academician A.P. Lisitsin from the Institute of Oceanology of the Russian Academy of Sciences in the late 1990s proposed the term "marginal filter", which includes five consecutive stages of self-purification of water in the mixing region: 1) gravity sedimentation of suspended matter, 2) coagulation of clay substance, 3) sorption of organic matter and iron oxyhydrates, 4)assimilation of dissolved biogenic elements by phytoplankton, and 5) filtration of phytoplankton by zooplankton, which ends with its transfer to the form of pellets falling on and turning into bottom sediments. In such marginal filters, 90-95% of suspended and 30-40% of dissolved matter of river discharge and contaminants are deposited (1).

There is another option for interaction between marine and freshwater environments: the formation of water bodies in which layers of salt and fresh water do not mix, but coexist. For such water bodies there is a special name - meromictic, in which seasonal water mixing is limited by the upper layer because water layers differ in density. Fresh runoff from the catchment, melting snow concentrate on the surface and dilute (or replace) only the surface layer.

Meromictic lakes of marine origin are widespread in regions of the sea regression, including Scandinavia, Kola Peninsula, White Sea, Kamchatka, Sakhalin, northern coast of Canada, and Antarctica. Over the past 7 years, on the coast of the Kandalaksha Gulf of the White Sea, we have discovered more than 20 such water bodies (2). They were formed due to the rapid postglacial uplift, which continues nowadays at a speed of about 40 cm per century. On the White Sea coast, you can find all the stages of isolation and reconstruct the sequence of succession of ecological communities.

Vertical hydrological structure of the lakes typically consists of five layers. 1. The upper layer from the surface to a depth of 1 m contacts the atmosphere, fresh water runoff, and tides (if the lake has not yet lost connection to the sea). This layer is homogeneous due to wind mixing. Its physico-chemical properties are very dynamic and highly dependent on the weather. 2. The next layer is the transition between the upper freshened and the underlying saline layers. It is characterized by a sharp salinity gradient and is therefore called a halocline, at the same time it can be considered as a pycnocline. 3. Immediately beneath it there is a water mass with the sea salinity and unusual characteristics that arise due to the greenhouse effect because of the insulation by upper freshened layer. In contrast to the common fresh and salty lakes, in the stratified salt water bodies in summer, the most heated layer is not the surface layer, but the middle one. Solar heat warms the bottom, it exchanges heat with adjoining water, and heat accumulates there. Similarly oxygen accumulates, which is formed as a result of photosynthesis of phytoplankton, and its concentration can reach up to 200-250% of saturation. 4. At a depth of 2.5-5 m, the aerobic layer is replaced by anaerobic one, another transition layer is located on their border - chemocline, or redox zone (transition area from oxidizing environment). Its thickness does not exceed 50 cm. Chemocline of the meromictic lakes on the White Sea chore usually is brightly colored. In the lakes that are at the early stage of separation they are red due to cryptophyte flagellates *Rhodomonas* sp. (3). The biomass of these microorganisms can reach almost 200 mg / l, this characterizes their abundance as a hyper-flowering (4). In the lakes more advanced in the separation from the sea so that the upper layer became completely fresh, the chemocline contains dense culture of green sulfur bacteria that perform anoxygenic photosynthesis (5). The peculiarity of this photosynthesis is that it is carried out under anaerobic conditions; for synthesis of organic substances, a hydrogen sulphide is used as a source of hydrogen instead of water molecule in “usual” photosynthesis, and as a result, not oxygen but sulfur is released. In the lakes with the cryptophyte layer, algae concentrate in the upper part of the chemocline, while the lower part is occupied by green sulfur bacteria. Cryptophyte algae are mixotrophic that means they are able not only to synthesize organic substances themselves, but also to use ready-made, including particles and bacteria. The cryptophyte cells are consumed by following trophic levels: infusorians, multicellular phytoplankton, which, in turn, feed large invertebrates and fish. Thus, the community of the separated lakes is based on the primary production of anoxygenic photosynthesis, which fundamentally distinguishes them from other aquatic ecosystems, including the original marine and final freshwater. 5. The bottom in the bottom depression is characterized by aphotic, anaerobic conditions, extremely poor fauna of eukaryotes or its complete absence, and a variety of bacteria that carry out numerous chemical reactions, including methanogenic archaea, methanotrophic bacteria, sulfate reducers, and many others.

Anoxygenic phototrophic bacteria play a very important role in the meromictic lakes separating from the sea: they stabilize the stratification of the reservoir. Assimilating hydrogen sulphide, the main source of which is located in the underlying water column, they prevent its diffusion into the inhabited upper layers. Thus, bacteria, on the one hand, support gradients of chemocline and possibly create them, and on the other hand protect the overlying communities from poisonous hydrogen sulphide. In addition, a dense suspension of bacteria absorbs light, and limits the photic zone. Below the chemocline, shadow and a low temperature are maintained throughout the year, which also contributes to the stability of vertical stratification.

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